UNIVERSITI SAINS MALAYSIA

First Semester Examination
2013/2014 Academic Session

December 2013/January 2014

EEM 101 – PRINCIPLES AND MECHANICS OF MATERIALS
[PRINSIP DAN MEKANIK BAHAN]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of <u>TEN</u> (10) pages and Appendix <u>EIGHT</u> (8) of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi <u>SEPULUH</u> (10) mukasurat dan Lampiran <u>LAPAN</u> (8) muka surat bercetak sebelum anda memulakan peperiksaan ini.]

<u>Instructions:</u> This question paper consists of <u>SIX</u> (6) questions. Answer **FIVE** (5) questions. All questions carry the same marks.

[***<u>Arahan:</u>*** *Kertas soalan ini mengandungi <u>ENAM</u> (6) soalan. Jawab **LIMA** (5) soalan. Semua soalan membawa jumlah markah yang sama.]*

Answer to any question must start on a new page.

[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru]

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. (a) Buktikan bahawa faktor kepadatan atom bagi struktur kubik berpusat muka, FCC ialah 0.74.

Verify that the atomic packing factor of FCC (face cubic centred) structure is 0.74.

(25 markah/*marks*)

(b) Kirakan parameter berikut:
Calculate these parameter:

(i) Kepadatan linear atom per milimeter bagi arah [1 0 0] dalam Iridium, yang berstruktur FCC, dengan pemalar kekisi, 0.3039 nm.

Linear atomic density in atoms per milimeter for the [1 0 0] direction in FCC iridium, with a lattice constant of 0.3039 nm

(20 markah/*marks*)

(ii) Kepadatan satah atom dalam setiap milimeter persegi bagi satah (1 1 1) dalam Kromium yang berstruktur BCC, dengan pemalar kekisi, 0.28846 nm.

The planar atomic density in atoms per square milimeter for the (1 1 1) plane in BCC chromium, with a lattice constant of 0.28846 nm.

(20 markah/*marks*)

(c) Pertimbangkan kepingan kerajang Aluminium 500 mm^2 dengan ketebalan 0.05 mm. Diberi pemalar kekisi Al ialah 0.405nm.

Consider a 500 mm^2 piece of Al foil with 0.05mm thickness. Given that lattive constant of Al is 0.405nm.

(i) Berapakah unit sel yang wujud dalam kerajang tersebut?

How many unit cells exist in the foil?

(ii) Jika kepadatan Al ialah 2.7 $g/cm^{3,}$ apakah jisim setiap sel?

If the density of Al is 2.7 g/cm^3, what is the mass of each cell?

(35 markah/*marks*)

2. (a) (i) Dalam larutan pepejal, terdapat dua jenis kecatatan titik bendasing iaitu gantian dan celahan. Terangkan dan bezakan kedua-duanya dengan bantuan rajah.

In solid solutions, there are two types of impurity point defects which are substitutional and interstitial. Describe and differentiate the two of of it with the aid of diagram.

(15 markah/*marks*)

(ii) Senaraikan dan terangkan secara ringkas kaedah perambatan retak.
List down and explain briefly the crack propagation methods.

(15 markah/*marks*)

(b) Satu kepingan aloi, 70% Cu- 30% Zn digelek sejukkan sebanyak 20 % kepada 3.0 mm. Kepingan itu seterusnya digelek sejukkan lagi kepada 2.00 mm.
Berapakah jumlah peratus kerja sejuknya?

A sheet of a 70% Cu-30% Zn alloy is cold rolled 20 % to a thickness of 3.0 mm. The sheet is then further cold-rolled to 2.00 mm.
What is the total percent cold work?

(30 markah/*marks*)

(c) Berikan definisi satah gelincir dan arah gelincir. Adakah setiap logam mempunyai sistem gelincir yang sama? Terangkan.

Define what is slip plane and slip direction. Do all metals have the same slip system? Explain.

Suatu kristal logam mempunyai struktur FCC dan dihalakan agar tegasan tegangan diaplikasikan sepanjang arah $\left[1\ 0\ \bar{2}\right]$. Jika gelincir terjadi pada satah (1 1 1) plane dan arah $\left[\bar{1}\ 0\ 1\right]$. Kira tegangan pada waktu kristal alah jika nilai tegangan ricih peleraiannya ialah 3.2 MPa.

A single crystal of metal has an FCC crystal structure and is oriented such that a tensile stress is applied along a $\left[1\ 0\ \bar{2}\right]$ *direction. If slips occurs on a (1 1 1) plane and in a* $\left[\bar{1}\ 0\ 1\right]$*. Compute the stress at which the crystal yields if its critical resolved shear stress is 3.2 MPa.*

(40 markah/*marks*)

3. (a) Tentukan secara ringkas apakah:

Define briefly what is:

(i) Patah mulur
Ductile fracture

(ii) Patah rapuh
Brittle fracture

(iii) Lesu
Fatigue

(iv) Keliatan patah
Fracture toughness

(v) Rayapan
Creep

(30 markah/*marks*)

(b) Terangkan proses penyepuhlindapan dengan menggunakan rajah yang bersesuaian. Dalam rajah yang sama, lakarkan bagaimana suhu penyepuhlindapan akan mempengaruhi kekuatan tegasan dan kemuluran bahan tersebut.

Describe the annealing process by using an appropriate diagram. In the same diagram, sketch how the annealing temperature will influence the value of tensile strength and ductility of the material.

(35 markah/*marks*)

(c) Satu spesimen logam aloi berbentuk silinder mempunyai diameter sebanyak 8.0 mm. Daya tegasan sebanyak 1000 N menghasilkan pengurangan diameter kenyal sebanyak 2.8 X 10^{-4} mm. Kira modulus kekenyalan bagi aloi tersebut jika diberi kadar Poisson ialah 0.30.

A cyclindrical specimen of a metal alloy has a diameter of 8.0 mm. A tensile force of 1000 N produces an elastic reduction in diameter of 2.8 X 10^{-4} mm. Compute the modulus of elasticity for this alloy, given that Poisson's ratio is 0.30.

(35 markah/*marks*)

4. (a) Terbitkan hubungan antara:
Derive the relationship between:

(i) Kilasan dan tegasan ricih
Torque and shear stress

(20 markah/marks)

(ii) Kilasan dan sudut kilasan.
Torque and angle of twist

(20 markah/marks)

(b) Satu aci keluli yang padu ditunjukkan dalam Rajah 4 menghantar kuasa masukan sebanyak 35kW pada kapi C kepada kapi A dan B. Kapi A mengeluarkan 15kW dan kapi B mengeluarkan 20kW. Tentukan tegasan ricih maksima di dalam aci-aci ini.

A solid steel shaft shown in Figure 4 transmits an input power of 35 kW at pulley C to pulleys A and B. Pulley A outputs 15 kW and pulley B outputs 20 kW. Determine the maximum shear stress in the shafts.

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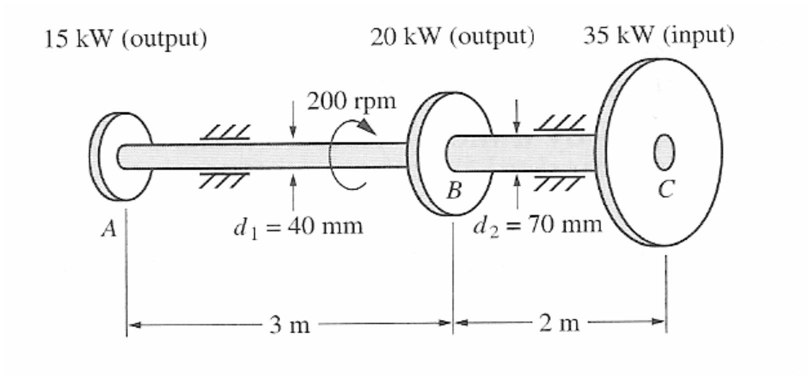


Rajah 4

Figure 4

(30 markah/marks)

(c) Buktikan bahawa sebutan bagi daya ricih yang mesti ditanggung oleh bolt:-

Prove that *the expression for the shear force that must be carried by the bolt:-*

$$F_s = p\frac{VQ}{I}$$

p ialah jarak antara bolt dan *V* ialah daya ricih pada bahagian itu

p is the pitch of the bolts and V is the shear force at the section

Q ialah momen pertama bagi kawasan terhadap paksi neutral dan *I* ialah momen inersia

Q is the first moment of area about the neutral axis and I is the moment of inertia

(30 markah/marks)

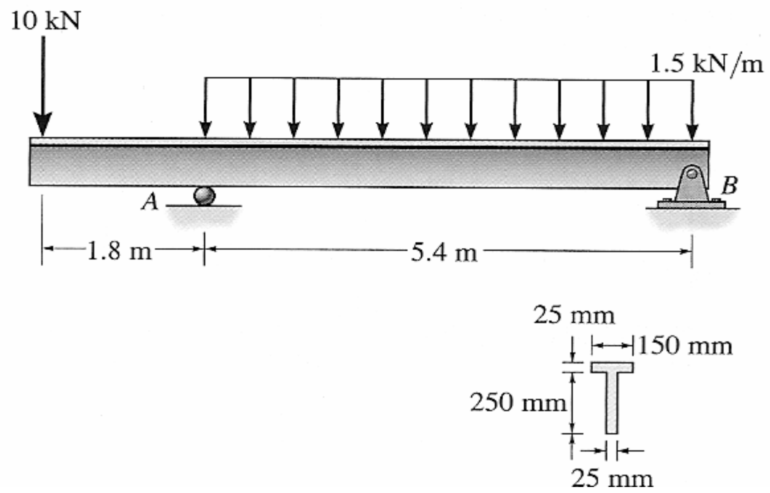
5. (a) Terangkan hubungan antara beban, ricih dan momen. Lukis lakaran yang sesuai.

Explain the relationship between load, shear and moment. Draw suitable sketches.

(30 markah/marks)

(b) Rasuk-T dikenakan beban seperti ditunjukkan di dalam Rajah 5.

The T-beam is subjected to the loading as shown in Figure 5.



Rajah 5

Figure 5

(i) Lukis rajah ricih dan momen bagi rasuk tersebut

Draw the shear and moment diagrams for the beam

(30 markah/marks)

(ii) Tentukan tegasan ricih maksima dan tegasan lenturan maksima bagi rasuk tersebut

Determine the maximum shear stress and the maximum flexural stress in the beam

(40 markah/marks)

6. (a) Terangkan hubungan antara lengkungan dan momen lenturan. Lukis lakaran yang sesuai.

Describe the relationship between curvature and bending moment. Draw suitable sketches.

(30 markah/marks)

(b) Kayu Southern Pine dengan 150 mm $\times$ 360 mm keratan rentas segiempat digunakan sebagai julur sepanjang 3 m. Kira lenturan maksima dan cerun maksima disebabkan beban seragam sebanyak 15 kN/m menggunakan:-

A 150 mm $\times$ 360 mm rectangular Southern pine section is used in a 3-m cantilever span beam. Compute the maximum deflection and the maximum slope due to a uniform load of 15 kN/m using:-

(i) Kaedah Formula
Formula Method

(20 markah/marks)

(ii) Kaedah Momen Luas
Moment Area Method

(20 markah/marks)

(iii) Bincangkan tegasan-tegasan di dalam rasuk Southern Pine menggunakan data yang diberikan oleh lampiran di muka surat 8.

Discuss the stresses in the Southern Pine beam using the data given by appendix in page 8.

(30 markah/marks)

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APPENDIX

CONSTANT VALUES

R – Gas constant (8.31 J/mol · K)

k – Boltzmann's constant

(1.38 x 10^{-23} J/atom · K , 8.62 x 10^{-5} eV/atom · K)

N_A – Avogadro's number (6.022 x 10^{23} atom/mol)

EQUATIONS

$$N_v = N\exp\left(-\frac{Q_v}{kT}\right)$$

$$N = \frac{N_A \rho}{A}$$

$$C_1 = \frac{m_1}{m_1 + m_2} \times 100$$

$$C_1' = \frac{n_{m1}}{n_{m1} + n_{m2}} \times 100$$

$$C_1' = \frac{C_1 A_2}{C_1 A_2 + C_2 A_1} \times 100$$

$$C_1 = \frac{C_1' A_1}{C_1' A_1 + C_2' A_2} \times 100$$

$$C_1'' = \left(\frac{C_1}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}}\right) \times 10^3$$

$$\rho_{\text{ave}} = \frac{100}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}}$$

$$A_{\text{ave}} = \frac{100}{\frac{C_1}{A_1} + \frac{C_2}{A_2}}$$

$$N = 2^{n-1}$$

Equation
$\tau_R = \sigma \cos\phi \cos\lambda$
$\tau_{\text{crss}} = \sigma_y(\cos\phi \cos\lambda)_{\max}$
$\sigma_y = \sigma_0 + k_y d^{-1/2}$
$\%CW = \left(\frac{A_0 - A_d}{A_0}\right) \times 100$
$d^n - d_0^n = Kt$

APPENDIX

$\sigma_c = \dfrac{K_{Ic}}{Y\sqrt{\pi a}}$
$a_c = \dfrac{1}{\pi}\left(\dfrac{K_{Ic}}{\sigma Y}\right)^2$
$\sigma_m = \dfrac{\sigma_{\max} + \sigma_{\min}}{2}$
$\sigma_r = \sigma_{\max} - \sigma_{\min}$
$\sigma_a = \dfrac{\sigma_{\max} - \sigma_{\min}}{2}$
$R = \dfrac{\sigma_{\min}}{\sigma_{\max}}$
$\sigma = \alpha_l E \Delta T$
$\dot{\epsilon}_s = K_1 \sigma^n$
$\dot{\epsilon}_s = K_2 \sigma^n \exp\left(-\dfrac{Q_c}{RT}\right)$
$T(C + \log t_r)$

Equation
$J = \dfrac{M}{At}$
$J = -D\dfrac{dC}{dx}$
$\dfrac{\partial C}{\partial t} = D\dfrac{\partial^2 C}{\partial x^2}$
$\dfrac{C_x - C_0}{C_s - C_0} = 1 - \operatorname{erf}\left(\dfrac{x}{2\sqrt{Dt}}\right)$
$D = D_0 \exp\left(-\dfrac{Q_d}{RT}\right)$

APPENDIX

Table 5.1 Tabulation of Error Function Values

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Table 5.2 A Tabulation of Diffusion Data

Diffusing Species	*Host Metal*	$D_0(m^2/s)$	*Activation Energy Q_d*		*Calculated Value*	
			kJ/mol	*eV/atom*	*T(°C)*	$D(m^2/s)$
Fe	α-Fe (BCC)	2.8×10^{-4}	251	2.60	500 900	3.0×10^{-21} 1.8×10^{-15}
Fe	γ-Fe (FCC)	5.0×10^{-5}	284	2.94	900 1100	1.1×10^{-17} 7.8×10^{-16}
C	α-Fe	6.2×10^{-7}	80	0.83	500 900	2.4×10^{-12} 1.7×10^{-10}
C	γ-Fe	2.3×10^{-5}	148	1.53	900 1100	5.9×10^{-12} 5.3×10^{-11}
Cu	Cu	7.8×10^{-5}	211	2.19	500	4.2×10^{-19}
Zn	Cu	2.4×10^{-5}	189	1.96	500	4.0×10^{-18}
Al	Al	2.3×10^{-4}	144	1.49	500	4.2×10^{-14}
Cu	Al	6.5×10^{-5}	136	1.41	500	4.1×10^{-14}
Mg	Al	1.2×10^{-4}	131	1.35	500	1.9×10^{-13}
Cu	Ni	2.7×10^{-5}	256	2.65	500	1.3×10^{-22}

Source: E. A. Brandes and G. B. Brook (Editors), *Smithells Metals Reference Book,* 7th edition, Butterworth-Heinemann, Oxford, 1992.

$$\sigma_T = \frac{F}{A_i}$$

$$\epsilon_T = \ln \frac{l_i}{l_0}$$

$$\sigma_T = K\epsilon_T^n$$

$$TS(\text{MPa}) = 3.45 \times \text{HB}$$

$$TS(\text{psi}) = 500 \times \text{HB}$$

$$\sigma_w = \frac{\sigma_y}{N}$$

Table 6.1 Room-Temperature Elastic and Shear Moduli and Poisson's Ratio for Various Metal Alloys

	Modulus of Elasticity		*Shear Modulus*		
Metal Alloy	*GPa*	*10^6 psi*	*GPa*	*10^6 psi*	*Poisson's Ratio*
Aluminum	69	10	25	3.6	0.33
Brass	97	14	37	5.4	0.34
Copper	110	16	46	6.7	0.34
Magnesium	45	6.5	17	2.5	0.29
Nickel	207	30	76	11.0	0.31
Steel	207	30	83	12.0	0.30
Titanium	107	15.5	45	6.5	0.34
Tungsten	407	59	160	23.2	0.28

APPENDIX

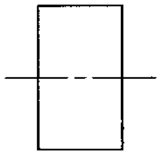
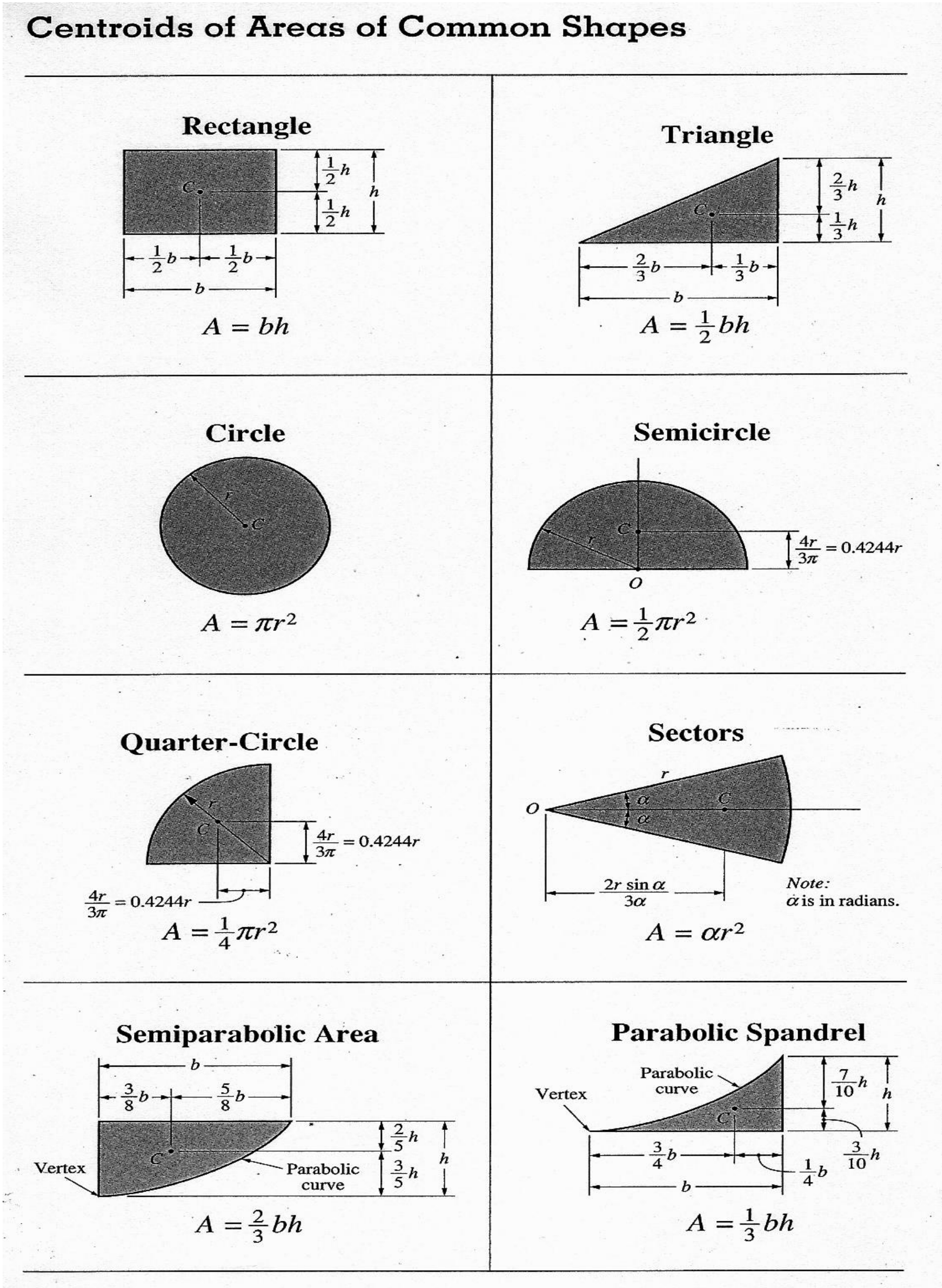


TABLE A–6(b) Properties of Structural Timber: SI Units

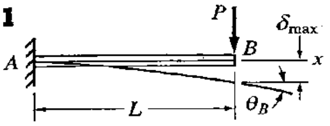
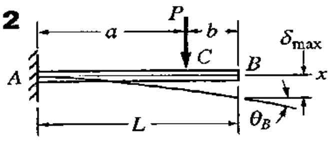
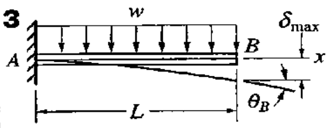
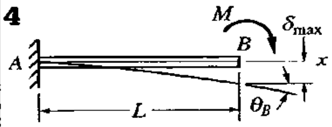
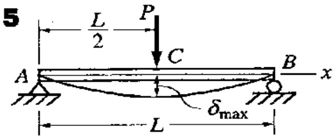
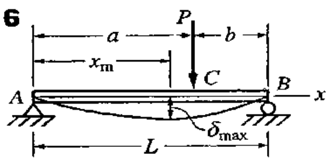
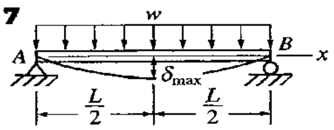
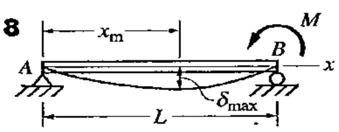
Nominal Size (mm)	Standard Dressed Size (mm)	Area of Section A ($\times 10^{-3}$ m^2)	Moment of Inertia I ($\times 10^{-6}$ m^4)	Section Modulus S ($\times 10^{-3}$ m^3)	Weight per ft w (kN/m)
50 × 100	38.1 × 88.9	3.39	2.23	0.0502	0.0213
× 150	× 140	5.32	8.66	0.124	0.0334
× 200	× 184	7.03	19.8	0.215	0.0441
× 260	× 235	8.97	41.2	0.351	0.0562
80 × 100	63.5 × 88.9	5.65	3.72	0.0836	0.0355
× 150	× 140	8.90	14.4	0.207	0.0557
× 200	× 184	11.7	33.0	0.359	0.0735
× 250	× 235	14.9	68.7	0.585	0.0937
× 300	× 286	18.1	124	0.864	0.114
100 × 100	88.9 × 88.9	7.94	5.20	0.117	0.0496
× 150	× 140	12.5	20.2	0.288	0.0781
× 200	× 184	16.4	46.2	0.503	0.103
× 250	× 235	20.9	96.1	0.818	0.130
× 300	× 286	25.4	173	1.21	0.159
× 360	× 337	29.9	282	1.67	0.188
150 × 150	140 × 140	19.5	31.8	0.454	0.123
× 200	× 191	26.6	80.3	0.851	0.168
× 250	× 241	33.7	164	1.36	0.212
× 300	× 292	40.8	290	1.98	0.257
× 360	× 343	47.9	469	2.74	0.301
× 410	× 394	55.0	710	3.61	0.346
× 460	× 445	62.1	1022	4.601	0.390
200 × 200	191 × 191	36.3	110	1.15	0.226
× 250	× 241	46.0	223	1.85	0.289
× 300	× 292	55.7	396	2.70	0.350
× 360	× 343	65.2	640	3.74	0.410
× 410	× 394	74.8	968	4.92	0.471
× 460	× 445	84.5	1390	6.28	0.533
× 510	× 495	94.2	1929	7.79	0.592
250 × 250	241 × 241	58.3	283	2.34	0.366
× 300	× 292	70.3	501	3.43	0.442
× 360	× 343	82.6	811	4.74	0.519
× 410	× 394	94.8	1230	6.23	0.597
× 460	× 445	107	1770	7.95	0.674
× 510	× 495	119	2440	9.87	0.751
× 560	× 546	132	3270	12.0	0.827

Note: Properties and weights are for dressed sizes. Weight per unit foot is based on an assumed average weight of 6.28 kN/m^3. Moment of inertia and section modulus are about the strong axis.

APPENDIX


Centroids of Areas of Common Shapes
Rectangle
$A = bh$
Triangle
$A = \frac{1}{2}bh$
Circle
$A = \pi r^2$
Semicircle
$\frac{4r}{3\pi} = 0.4244r$
$A = \frac{1}{2}\pi r^2$
Quarter-Circle
$\frac{4r}{3\pi} = 0.4244r$
$A = \frac{1}{4}\pi r^2$
Sectors
$\frac{2r \sin\alpha}{3\alpha}$
Note: α is in radians.
$A = \alpha r^2$
Semiparabolic Area
Vertex
Parabolic curve
$A = \frac{2}{3}bh$
Parabolic Spandrel
Vertex
Parabolic curve
$A = \frac{1}{3}bh$

APPENDIX

Beam Loading and Deflection	Maximum Deflection	Slope at End(s)	Deflection Equations
1 	$\delta_{max} = \dfrac{PL^3}{3EI}$	$\theta_B = \dfrac{PL^2}{2EI}$	$\delta = \dfrac{Px^2}{6EI}(3L - x)$
2 	$\delta_{max} = \dfrac{Pa^2}{6EI}(3L - a)$	$\theta_B = \dfrac{Pa^2}{2EI}$	$\delta_{AC} = \dfrac{Px^2}{6EI}(3a - x)$ $\delta_{CB} = \dfrac{Pa^2}{6EI}(3x - a)$
3 	$\delta_{max} = \dfrac{wL^4}{8EI}$	$\theta_B = \dfrac{wL^3}{6EI}$	$\delta = \dfrac{wx^2}{24EI}(x^2 - 4Lx + 6L^2)$
4 	$\delta_{max} = \dfrac{ML^2}{2EI}$	$\theta_B = \dfrac{ML}{EI}$	$\delta = \dfrac{Mx^2}{2EI}$
5 	$\delta_{max} = \dfrac{PL^3}{48EI}$	$\theta_A = \theta_B = \dfrac{PL^2}{16EI}$	$\delta_{AC} = \dfrac{Px}{48EI}(3L^2 - 4x^2)$
6 	For $a > b$: $\delta_{max} = \dfrac{Pb(L^2 - b^2)^{3/2}}{9\sqrt{3}EIL}$ at $x_m = \sqrt{\dfrac{L^2 - b^2}{3}}$	$\theta_A = \dfrac{Pb(L^2 - b^2)}{6EIL}$ $\theta_B = \dfrac{Pa(L^2 - a^2)}{6EIL}$	$\delta_{AC} = \dfrac{Pbx}{6EIL}(L^2 - x^2 - b^2)$ $\delta_{CB} = \dfrac{Pb}{6EIL}\left[\dfrac{L}{b}(x - a)^3 + (L^2 - b^2)x - x^3\right]$
7 	$\delta_{max} = \dfrac{5wL^4}{384EI}$	$\theta_A = \theta_B = \dfrac{wL^3}{24EI}$	$\delta = \dfrac{wx}{24EI}(L^3 + x^3 - 2Lx^2)$
8 	$\delta_{max} = \dfrac{ML^2}{9\sqrt{3}EI}$ at $x_m = \dfrac{L}{\sqrt{3}}$	$\theta_A = \dfrac{ML}{6EI}$ $\theta_B = \dfrac{ML}{3EI}$	$\delta = \dfrac{Mx}{6EIL}(L^2 - x^2)$

APPENDIX

TABLE A–7(b) Typical Mechanical Properties of Common Materials: SI Units

Material	Specific Weight	Modulus of Elasticity	Modulus of Rigidity	Yield Strength		Ultimate Strength			Coefficient of Thermal Expansion
				Tension	Shear	Tension	Compression	Shear	
	γ (kN/m³)	E (GPa)	G (GPa)	σ_y (MPa)	τ_y (MPa)	$(\sigma_u)_t$ (MPa)	$(\sigma_u)_c$ (MPa)	τ_u (MPa)	α ($\times 10^{-6}$/°C)
Steel:									
ASTM-A36 (carbon)	77	210	83	250	145	400			12
ASTM-A441 (alloy)	77	210	83	320		460			12
AISI 1020 (hot rolled)	77	210	79	210		380			12
AISI 1040 (hot rolled)	77	210	79	290		520			12
Stainless steel (annealed)	77	210	80	260	152	590			17
Cast Iron:									
Gray cast iron	71	90	41			170	620	221	10
Malleable cast iron	72	170	83	230		350	620	331	12
Aluminum:									
Alloy 2014-T6	27	75	27	400	228	460		276	23.0
Alloy 2024-T4	27	73		320		470		283	23.2
Alloy 6061-T6	27	70	26	240	138	260		165	23.6
Copper:									
Annealed	87	120	44	69		220		152	17
Hard-drawn	87	120	44	370		390		200	17
Alloys:									
Magnesium alloy	17	45	17	150		280		145	25.2
Titanium alloy	43	110	45	830		900		690	9.5
Timber:									
Douglas-fir	4.7	13				100	50	7.6	
Westen white pine	4.9	12					35	9.7	
Southern pine	5.7	12					58	10	
White oak	6.8	12					51	14	
Red oak	6.4	12					47	12	
Western hemlock	4.4	11				90	50	9.0	
California redwood	4.1	9.0				66	42	6.2	
Concrete:									
Medium strength	24	25					28		9.9
High strength	24	31					41		9.9